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Effects of Nitrogen and Phosphorus Fertilizers on Deer Browsing and Growth of Young Douglas-Fir

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Abstract

Nitrogen and phosphorus were applied to young Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees to determine their effects on deer browsing and tree growth. Nitrogen (N) produced measurable responses in browsing of terminal shoots and growth of trees the 1st year, but effects were mostly negligible 2 years after treatments. No responses to phosphorus (P) were detected. Nitrogen and N+P treatments increased the concentration of N in tree foliage the 1st year, but amount of moisture, ash, calcium, and P were not affected after 2 years.

Keywords: Browse preference, nitrogen fertilizer response, phosphate fertilizer response, Douglas-fir, *Pseudotsuga menziesii*.

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Introduction

Browsing by black-tailed deer (Odocoileus hemionus columbianus Rafinesque) causes serious damage to young Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) on certain areas in the Pacific Northwest (Black et al. 1979, Crouch 1969). Methods to control damage include application of chemical repellants (Radwan 1963, Rochelle et al. 1974) fencing or caging the trees (Campbell and Evans 1975; Crouch, in press), and seeding plants that may be more attractive than the trees to deer (Campbell 1974). Among possible control methods not previously evaluated is selective application of nutrients to the trees.

Fertilization affects growth and chemical composition of plants, including Douglas-fir, and animals' preference for them (Geist et al. 1974; Gessel and Walker 1956; Gessel and Orians 1966; Gibbens and Pieper 1962; Mitchell and Hosley 1936; Oh et al. 1970; Radwan et al. 1971, 1974).

On areas where damage by deer is detrimental, application of fertilizers might stimulate height growth and enable trees to grow beyond the reach of deer more quickly if the incidence and severity of browsing were not also increased. Also, if deer preferred to feed on treated trees, browsing pressure might be confined to fertilized trees, allowing untreated trees to grow normally.

In this study we applied nitrogen (N) and phosphorus (P) fertilizers, singly and in combination to individual Douglas-fir trees growing on areas of above-average productivity. We observed effects of the treatments on height and diameter growth and relative preference by black-tailed deer. We also determined concentration of selected chemical elements in current year foliage.

Study Areas

Two areas in the Coast Ranges were studied, one in Washington and one in Oregon.

The Washington site was on State-owned land in the Capitol Forest west of Olympia. It was located on a gentle, east-facing slope, at 1,600-foot elevation.[1] Annual precipitation at the nearest weather station averaged 68 inches during the study period. The area, clearcut prior to 1930, had burned and reburned. Douglas-fir had been planted at least twice, most recently in 1957, and the stocking level averaged 550 trees per acre. The trees ranged from 2 to 6 feet in height, and most were severely browsed in June and early July each year (Crouch 1968). Total nonconifer plant cover averaged over 60 percent in 1967; hairy cats-ear (*Hypochaeris radicata* L.),[2] velvet-grass (*Holcus lanatus* L.), and Pacific blackberry (*Rubus ursinus* Cham. & Schlect.) were important contributors to the understory flora. Moderate numbers of deer used the area in late spring, summer, and fall each year.

The Oregon site, located on the Siuslaw National Forest southwest of Alsea, was on a moderate, northwest-facing slope at 1,300-foot elevation. Annual precipitation at the nearest station averaged 94 inches for the study period. The area had been clearcut, slash burned, and Douglas-fir planted in 1961, 7 years before this study. The stocking level averaged 450 trees per acre, and trees ranged from 2 to 6 feet in height. Nonconifer plant cover averaged over 80 percent; major species included thimbleberry (*Rubus parviflorus* Nutt.), hairy cats-ear, bracken (*Pteridium aquilinum* Gled.), deer vetch (*Lotus crassifolius* (Benth.) Greene), and velvet grass. Moderate numbers of deer frequented the area all year, but browsing on Douglas-fir was minimal during all seasons.

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[1]Metric equivalents are given on page 13.
[2]Plant names are from Hitchcock and Cronquist (1973).

Materials and Methods

Sample trees.--Douglas-fir 2 to 5 feet tall were used. Trees on both sites had grown well when not heavily browsed and showed no signs of nutrient deficiencies. It was expected that deer would browse the terminal shoots of trees easily within their reach and thereby mask effects that fertilizers might have on height growth. To circumvent this and still allow deer access to all the trees, two height classes were selected. One group of trees ranged from 2 to 3.5 feet and was deemed highly susceptible to terminal browsing. These trees are called shorter trees. The second group, ranging from 4 to 5 feet and considered reasonably safe from terminal browsing, are called taller trees. Heights were measured before treatment. Effects of fertilizers on 300 sample trees in five blocks of 60 trees each at each location were evaluated. Within blocks, 40 shorter trees and 20 taller trees were selected and marked with wooden stakes. Treatments were then assigned at random to 10 shorter and 5 taller trees in each block so that each treatment was represented by 50 shorter and 25 taller trees at each location.

Fertilizers.--Two commercial fertilizers in granular form were used: urea (46-percent N) and single superphosphate [30-percent $CaH_4(PO_4)_2$ and 50-percent $CaSO_4$]. The fertilizers were applied singly and in combination to give three treatments: (a) 45 g N, (b) 45 g P_2O_5, and (c) 45 g N + 45 g P_2O_5. In addition there was an untreated control. These rates are equivalent to 200 lb/acre of N or P and a combination of 200 lb/acre of each.

In addition to urea, each tree in the N treatment received gypsum containing an amount of calcium (Ca) equivalent to that in each of the P_2O_5 and the $N+P_2O_5$ treatments and an amount of sulfur exceeding by only a few grams the sulfur in the P_2O_5 and the $N+P_2O_5$ treatments. Thus, sulfur was the only unbalanced variable among the three fertilizer treatments.

In March 1968 fertilizers were broadcast by hand over a circular area centered at the tree stem and extending about a foot beyond its dripline.

Evaluation of treatments.--Effects on browsing and growth were determined by inspecting the sample trees for evidence of browsing and by measuring their heights at predetermined intervals.

In Washington, the sample trees were examined and terminal leaders measured in June, July, and late September 1968, and in April, June, and October 1969. Unexpected precommercial thinning on this site precluded further examination.

In Oregon, the sample trees were inspected and terminals measured biweekly after treatment in March through September 1968, monthly thereafter through September 1969, and a final measurement was made in November 1971.

Effects on diameter growth were estimated from sections taken from two taller trees from each treatment in each block at 1 foot above the ground in January 1970. Diameters of the Oregon trees were measured again in November 1971 by a diameter tape placed 1 foot above the ground.

Chemical composition.--Tissue samples from current year growth were taken from trees on the Washington site only. Shorter trees representative of all treatments were sampled in mid-June in 1968 and 1969, during the peak of deer browsing. Composite samples were obtained by clipping several 2-inch tips of secondary lateral shoots from each tree. Samples were immediately placed in precooled glass jars and transported to the laboratory in a portable cooler.

Moisture content was determined by drying subsamples of tissues to constant weight in a forced-air oven at 65°C, grinding the dried tissue, and estimating the ash in the ground tissue after heating it at 500°-550°C for 4 hours. Total nitrogen (including nitrate) was determined by the micro-Kjeldahl procedure, calcium by a titrimetric method, and phosphorus by the molybdenum blue technique (Chapman and Pratt 1961).

Statistical analysis.--Data were subjected to analyses of variance, and means were separated according to Tukey (Snedecor 1961) as appropriate. Percentages were transformed to arcsin values before analysis.

Results

By late April, about 1 month after fertilization, grasses adjacent to trees treated with N and N+P were more abundant and noticeably darker green in color than those receiving the other treatments. No differences in the trees themselves were observed.

In late June, at the peak of deer browsing on the Washington site, some shorter trees treated with N+P were almost obscured by grass (fig. 1).

Deer Browsing

Washington site.--In 1968, the 1st year after treatments, the sequence and intensity of browsing were similar to those recorded a year earlier on that area (Crouch 1968). Browsing began shortly after bud burst in May, peaked in late June, and virtually ceased in late July. For all treatments, browsing of terminal shoots of shorter trees averaged 70 percent in 1968 (table 1). More terminal shoots were browsed on trees receiving only nitrogen than on those in other treatments. In 1969, terminal shoots of even the shorter trees were beyond easy reach of deer, and effects of treatment could not be evaluated.

In 1968, deer browsed at least one lateral shoot on more than 90 percent of the trees in both height classes, but percentages of available shoots browsed did not vary with treatments (table 1). In 1969, deer browsed lateral shoots on 80 percent of the trees, but no effects of treatment were observed.

No trees were browsed between September and May in either year. Snowshoe hare (Lepus americanus Erxleben) clipped a few lateral shoots during both winters, but percentages did not differ among treatments.

Oregon site.--Few trees of either height class were browsed despite the presence of deer throughout the year (table 1). Treatments had no measurable effect on browsing of either terminal or lateral shoots in 1968 or 1969.

A

B

Figure 1.--Shorter trees marked by 30-inch wooden stakes on the Washington site: A, untreated tree in center foreground and nitrogen-treated tree obscured by velvet grass in left background; B, nitrogen+phosphorus-treated tree engulfed by herbaceous vegetation.

Table 1--Percentage of young Douglas-fir shoots browsed by deer after treatment with nitrogen (N) and phosphorus (P) in Washington and Oregon[1]

Years after treatment and shoots examined	Shorter trees				Taller trees			
	Control	N	P	N+P	Control	N	P	N+P
				CAPITOL FOREST, WASHINGTON				
1st year:								
Terminal shoots	64a	78b	70a	68a	[2]	[2]	[2]	[2]
Lateral shoots	12	13	13	13	10	13	9	11
2d year:								
Lateral shoots	4	5	5	5	3	2	3	2
				ALSEA, OREGON				
1st year:								
Terminal shoots	4	4	5	4	[2]	[2]	[2]	[2]
Lateral shoots	<1	<1	<1	<1	<1	<1	<1	<1
2d year:								
Lateral shoots	<1	<1	<1	<1	<1	<1	<1	<1

[1] Commercial fertilizers were applied to individual trees in March 1968 at 45 grams N or 45 grams P_2O_5 per tree or both. Means within years and locations followed by no letter or the same letter are not significantly different at P=0.05.

[2] Mostly beyond the reach of deer.

Height Growth

Washington site.--Height growth of all shorter trees averaged 1.66 feet the 1st year. Shorter trees treated only with N and browsed more heavily grew less than those receiving the other treatments (table 2). Height growth of shorter trees averaged 1.95 feet the 2d year and showed no differences among treatments.

Taller trees grew an average of 2.86 feet the 1st year and 2.50 the 2d.

After two growing seasons, heights of all trees were not significantly affected by treatment (table 2).

Table 2--Height growth of young Douglas-fir trees treated with nitrogen (N) and phosphorus (P) in Washington and Oregon[1]/

Height and growth	Unit	Shorter trees				Taller trees			
		Control	N	P	N+P	Control	N	P	N+P
					CAPITOL FOREST, WASHINGTON				
Pretreatment height	Feet	3.10	3.09	3.10	3.07	4.26	4.31	4.20	4.33
Growth after treatment:									
1st year	Percent	60a	44b	55a	56a	69	67	67	64
2d year	Percent	29	30	29	29	35	38	35	32
Height 2 years after treatment	Feet	7.01	6.27	6.65	6.76	9.53	9.91	9.45	9.38
					ALSEA, OREGON				
Pretreatment height	Feet	2.97	2.86	2.91	3.01	4.26	4.29	4.26	4.24
Growth after treatment:									
1st year	Percent	48b	56a	48b	51b	39b	48a	38b	40b
2d year	Percent	36	36	38	36	29b	33a	29b	30b
Height 2 years after treatment	Feet	6.02	6.10	5.90	6.18	7.66b	8.37a	7.68b	7.72b
Height 4 years after treatment	Feet	10.80	10.90	11.05	11.02	13.64	13.80	13.25	13.36

1/Commercial fertilizers were applied to individual trees in March 1968 at 45 grams N or 45 grams P_2O_5 per tree or both. Means within categories and locations followed by no letter or the same letter are not significantly different at P=0.05.

Oregon site.--Among all treatments, shorter trees grew 1.49 feet the 1st year and 1.58 the 2d; taller trees, 1.76 and 1.82 feet. Application of N alone produced small but significant increases in height growth of both shorter and taller trees the 1st year (table 2). Taller trees treated only with N also grew more than those of the other treatments the 2d year, but shorter trees did not show this response.

After two growing seasons, heights of the taller N-treated trees were significantly greater than those of taller trees receiving the other treatments, but there were no significant differences among treatments in the heights of the shorter trees.

Results of a final measurement of height in 1971, 4 years after fertilization, showed no significant differences by treatment among either the shorter or taller trees.

Diameter Growth

Washington site.--Treatments had no measurable effect on diameter growth of the taller trees in either the first or second growing seasons (table 3). After 2 years, trees of all treatments had grown an average of 0.88 inch. Trees averaged 1.74 inches in diameter compared with 0.86 inch before treatment.

Oregon site.--Diameter growth of the taller trees was not affected by treatment in 1968 and 1969 or after the fourth growing season in 1971. Among all treatments, the 2-year mean diameter growth was 0.68 inch. Diameters averaged 0.54 inch when first measured and 1.23 inches after two growing seasons. After 4 years, the trees had grown an average of 1.81 inches and mean diameter at 1 foot above the ground was 2.36 inches.

Table 3--Diameter growth at 1 foot above the ground of 4- to 5-foot Douglas-fir trees treated with nitrogen (N) and phosphorus (P) in Washington and Oregon[1/]

Diameter and growth	Unit	Treatments			
		Control	N	P	N+P
		CAPITOL FOREST, WASHINGTON			
Pretreatment diameter (March 1968)	Inch	0.86	0.87	0.83	0.86
Growth after treatment:					
1st year	Percent	46	46	46	46
2d year	Percent	38	38	41	39
Diameter 2 years after treatment	Inches	1.74	1.74	1.71	1.75
		ALSEA, OREGON			
Pretreatment diameter (March 1968)	Inch	.54	.54	.54	.57
Growth after treatment:					
1st year	Percent	57	60	58	60
2d year	Percent	43	43	44	40
Diameter 2 years after treatment	Inches	1.22	1.23	1.21	1.28
Diameter 4 years after treatment	Inches	2.32	2.35	2.38	2.39
4-year diameter growth	Inches	1.78	1.81	1.84	1.82

[1/] Commercial fertilizers were applied to individual trees in March 1968 at 45 grams N or 45 grams P_2O_5 per tree or both. Treatment means were not significantly different (P=0.05) among treatments within years.

Chemical Composition

Chemical analysis was confined to shoots collected 1 and 2 years after fertilization on the Washington site.

Treatments had not affected concentrations of moisture, ash, Ca, or P 1 year after application of fertilizers (table 4). Only total N varied significantly among treatments; it was significantly higher in shoots of trees supplied with urea than in tissues of trees receiving other treatments. Average concentration of moisture was 66.94 percent; ash, 2.06; total N, 1.22; Ca, 0.25; and P, 0.15.

In the second growing season, moisture averaged 67.58 percent; ash, 1.80; total N, 1.12; Ca, 0.22; and P, 0.15. Levels of the different constituents did not differ by treatment and varied little from concentrations found 1 year earlier.

Table 4--Concentration of selected chemical constituents in shoots of young Douglas-fir trees treated with nitrogen and phosphorus in Washington[1]

Treatment	Moisture	Ash	Total nitrogen	Calcium	Phosphorus
	------------	Percent of dry weight	------------		
		1968 COLLECTION			
Control	67.31	2.12	1.15a	0.26	0.15
Nitrogen	66.03	2.04	1.28b	.25	.14
Phosphorus	66.80	2.06	1.17a	.25	.16
Nitrogen plus phosphorus	67.63	2.03	1.30b	.23	.14
		1969 COLLECTION			
Control	66.98	1.79	1.11	.22	
Nitrogen	67.60	1.80			
Phosphorus	68.07	1.79			
Nitrogen plus phosphorus	67.69	1.82			

[1]Commercial fertilizers were applied individually at the rate of 45 grams N or 45 grams P_2O_5 per tre averages of 3 composite samples from 10 trees each. means in each column followed by no letter or the significantly different at P=0.05.

Discussion and Conclusions

Overall effects of applications of nitrogen and phosphorus were minimal and much less than those reported elsewhere on Douglas-fir and other species.

Significantly greater browsing on terminal shoots of the N-treated shorter trees in Washington resulted in significantly less height growth than that of the other sample trees the 1st year after treatment, but this effect was erased in the second growing season. Whether the increased browsing stimulated by N would have persisted had the trees initially been shorter and their terminals available to deer for a longer period is not known.

The increase in height growth the 1st year among the shorter N-treated trees in Oregon was not repeated the 2d year and could not be detected after two growing seasons. The increase in height growth of taller trees the 1st and 2d years after treatment with N was reflected in tree heights after 2 years but disappeared by the 4th year after treatment.

The greater height growth of the taller trees in Washington compared with that of trees in Oregon supports the contention that heavily browsed trees may develop nearly normal root systems and are capable of accelerated growth when released from browsing pressure. The Washington trees were planted in 1957 and had been heavily browsed before the study was installed. They averaged 4.28 feet in height and 0.86 inch in diameter 1 foot above the ground in March 1968. The Oregon stock was planted in 1961 and averaged 4.26 feet in height, but the mean diameter was only 0.55 inch. These trees showed little evidence of past browsing. After two growing seasons, the trees in Washington averaged 9.57 feet in height and 1.74 inches in diameter; trees in Oregon 7.86 feet and 1.24 inches.

In Washington, concentrations of N in foliage of trees supplied with urea were higher than in foliage from trees of the other treatments, indicating that added N was taken up by the trees. The lack of growth response to N and P in Washington and the relatively small response to N in Oregon, however, suggest that availability of these nutrients was not limiting growth on either study area before treatment. On the other hand, more efficient uptake and utilization of the added nutrients by competing vegetation could also explain the response observed (fig. 1). This possibility is indicated on the Washington site where grass responded dramatically to N and even more to N plus P. Fixation of added P by the soil could also provide another explanation for lack of growth response of the trees to the superphosphate applied.

Results show that application of N and P, singly and in combination, to individual Douglas-fir trees growing on two sites of above-average productivity did not affect the young trees sufficiently to be of any practical importance. Whether similar treatments will have beneficial effects when used on lower sites is not known.

Metric Equivalents

1 acre = 0.405 hectare
1 foot = 0.305 meter
1 inch = 2.54 centimeters
1 pound per acre = 0.892 kilogram per hectare

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